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REDEFINITION OF THE FOUR FUNDAMENTAL FORCES.(U)
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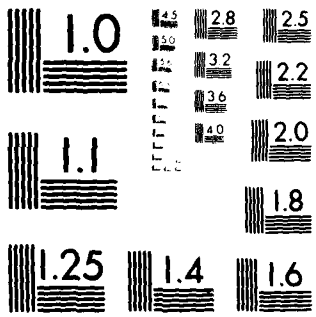

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REDEFINITION OF THE FOUR FUNDAMENTAL FORCES

JUN 1980

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INTRODUCTION

Unification of the fundamental forces has been one of the great theoretical problems in physics in the twentieth century. Beginning in 1918 with Weyl and continuing through the last thirty-five years of Einstein's life, many different attempts were made to unify the electromagnetic and the gravitational forces. Moreover, since the four fundamental forces were first defined in the early forties, extensive efforts by numerous investigators have gone into measuring and attempting to unify two or more of these forces. This paper defines the four forces and discusses some of the difficulties in unifying the forces. A new approach to unification will be presented with a discussion of the consequences and predictions of this approach.

The four fundamental forces are defined in Table 1. These four forces are all that are necessary to characterize all phenomena. From an Army perspective, the strong force is only of interest in the basic structure of matter and in nuclear weapons effects. The electromagnetic force is involved in the structure of matter, all electronic devices, all chemical reactions, explosives, and propellants. The weak force occurs in nuclear weapons effects. The gravitational force becomes involved in every load carrying device and in the motion of aircraft, projectiles and missiles. Frequently, such as in a fuze, more than one force is involved.

Table 1. Four fundamental forces. Adapted from 1, p. 52 and 2, p. 453. One fermi (fm) is 10^{-13} centimeter.

Force	Natural Occurrences	Relative Strength	Range
Strong	Nuclear Forces	1	0.5 to 1 fm
Electromagnetic	Atomic Forces	10^{-2}	0.01 fm to Indefinite
Weak	Radioactive Decay	10^{-5} - 10^{-13}	Singularity to 0.01 fm
Gravitational	Astronomical Forces	10^{-39}	Point Source to Indefinite

The four forces are generally listed in the order of increasing strength as represented by their coupling constants. These coupling constants are essentially the ratios of the strengths of the indicated force to the strength of the strong force. Thus, the strong force, which is the strongest, has a coupling constant of unity when compared to itself. The strong interaction is 137 times greater in strength than the electromagnetic force and about 10^{39} times greater than the gravitational force, so that the coupling constants for these two forces are 10^{-2} and 10^{-39}, respectively. The weak force coupling constant is quoted at various magnitudes: 10^{-13}, 10^{-7}, or the Fermi theory value of 1.02×10^{-5}. These coupling constants have become the universally accepted way of fingerprinting the four forces.

Any effort to try to understand the four forces and to achieve unification must cope with a vast array of variables. Not all of these variables can be explained here. There are different forces, forms of interaction, effects on matter, relative strengths, spins, ranges, variations with range, mediators, saturation effects, charges, and selection rules. Even the interpretation of what unification means may take different paths. Hardly a single thread of continuity runs through the four forces.

A detailed review was made of various approaches to unification of the four forces and of the variables that were identified in the approaches. A side-by-side comparison of the different assumptions and steps in Weyl's, Einstein's, guage symmetry, and supergravity approaches to unification led to the following observation. It was observed that the only uniform step that everyone has adopted to date is the _a priori_ assumption that two or more of the strong, electromagnetic, weak and gravitational forces are accepted without question. The almost completely independent way of theoretically defining and measuring the four forces, the limited success of indirect unification through families of mediating particles, the extraordinary complexity of the mathematics, the omission of general relativity from the theories, and the sheer intensity of unfulfilled efforts confirm the need to possibly question even the _a priori_ assumption. Consequently, the primary basis of this paper is that, it may be possible that unification might be easier to achieve if the _a priori_ statement of the four forces is redefined.

REDEFINITION

The phenomena that led to the definition of the four forces in the first place is accepted at face value. Only a new explanation is needed. Two of the forces have a strong justification for being retained unchanged. These are the electromagnetic and the gravitational interactions. There are several similarities between these two, especially when compared in their simple forms of the Coulomb electrostatic force and the Newton inverse square law. Both are static, point-source, inverse square relationships. Each has a potential that is similarly defined. They have both been verified over ranges from less than one fermi to galactic distances. An alternate explanation of the four forces is that there are other forces or potentials very much like those of Coulomb and Newton which could explain the phenomena associated with the strong and the weak forces. This alternative, if applied rigorously, leads to a result which, at first glance, is counterintuitive but in the final analysis fulfills almost all predictions expected for unification. It is hypothesized that $E = mc^2$ and $E = h\nu$ are functions of potentials which represent corresponding forces in the structure of matter. One of these forces is called the Einstein force and the other is the Planck force, respectively. When combined with the Coulomb and Newton forces, as indicated in Table 2, the redefined fundamental forces are referred to as the unified interaction theory (first published as a paper in reference 3).

Table 2. Redefined forces and interactions of the unified interaction theory.

Interaction	Force	Equation
Strong	Einstein	$\vec{F}_c = \frac{mc^2}{r}$
Quantum	Planck	$\vec{F}_h = \frac{hc}{2\pi r^2}$
Electromagnetic	Coulomb	$\vec{F}_e = \frac{e^2}{r^2}$
Gravitational	Newton	$\vec{F}_G = \frac{m^2G}{r^2}$

The redefined interactions consisting of the strong, quantum, electromagnetic and gravitational interactions replace the currently accepted strong, electromagnetic, weak and gravitational interactions. The new list of interactions are specifically defined by the forces (first published in abstract form in reference 4) listed in Table 2. Each force has a definite equation. Three of the forces are inverse square and one is inverse linear with distance. All forces are defined in terms of point-source, static interactions between two masses. The Einstein force is identified as the strong interaction. This force is essentially a rest mass energy gradient. The Planck force defines a new interaction, the quantum interaction, which will be explained in a later section. The Coulomb and Newton Forces are accepted without any new interpretation. The Coulomb force is related to the electromagnetic interaction only in terms of the electrostatic component.

CORRELATIONS AND PREDICTIONS

Four criteria are used to assess the unified interaction theory; mathematical correlation of known relationships; physical correlation with measured phenomena; fulfillment of predictions expected of a unified theory; and, unique predictions of the new theory. These criteria will be applied in the following manner. First, relationships mathematically deduced from the four redefined

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forces will be presented. Then, the criteria of physical measurements, unification predictions, and unique predictions will be explained for the Einstein and Planck forces. Finally, the criteria will be applied to the theory in general.

Based only upon the four redefined forces of the unified interaction theory, it is possible to deduce several functions and relationships that are either well-known or cited in the scientific literature. Only the consideration of equivalency conditions or ratios are needed to make these mathematical correlations. Figure 1, on the following page, has been especially structured to graphically aid in showing these mathematical correlations and in describing different phenomena. In fact, over thirty different concepts mentioned in this paper are keyed to Figure 1. The absolute magnitudes of the four redefined forces in Table 2 are displayed in Figure 1 as a plot of logarithm of force versus logarithm of distance. Values on the ordinate and abscissa correspond to calculations based upon an idealized point source interaction between two protons. Figure 1 was originally made to scale but has been condensed and somewhat distorted to fit a more convenient size. Points K, M, O, P, Q, R, S, and T will all be used to illustrate some phenomena or particular relationship. Letters for the points were generally chosen to provide some key to each illustration. The results to be described with the aid of Figure 1 could just as well be shown on a linear plot of force versus distance but it would not have been as convenient. The reader may verify any of the results indicated in the following statements. Generally, the last term in each sentence is the function or relationship obtained from performing the operation stated.

Equivalent conditions of force and distance are indicated at points Q, O, and S in Figure 1. The equivalence between the Einstein force and the Planck force magnitudes, when $F_c = F_h$ at point Q, occurs at a distance defined by the Compton wavelength. Similarly, the Einstein force is equal to the Coulomb force, $F_c = F_e$ for point O, at the classical radius. The Einstein force is equivalent to the Newton force, $F_c = F_G$, at the gravitational collapse limit, or one-half the Schwartzchild limit at point S. If the equation for the Newton force is stated at the gravitational collapse limit, the result is a constant force, F_S, which has previously gone unnoticed in the Einstein field equations.

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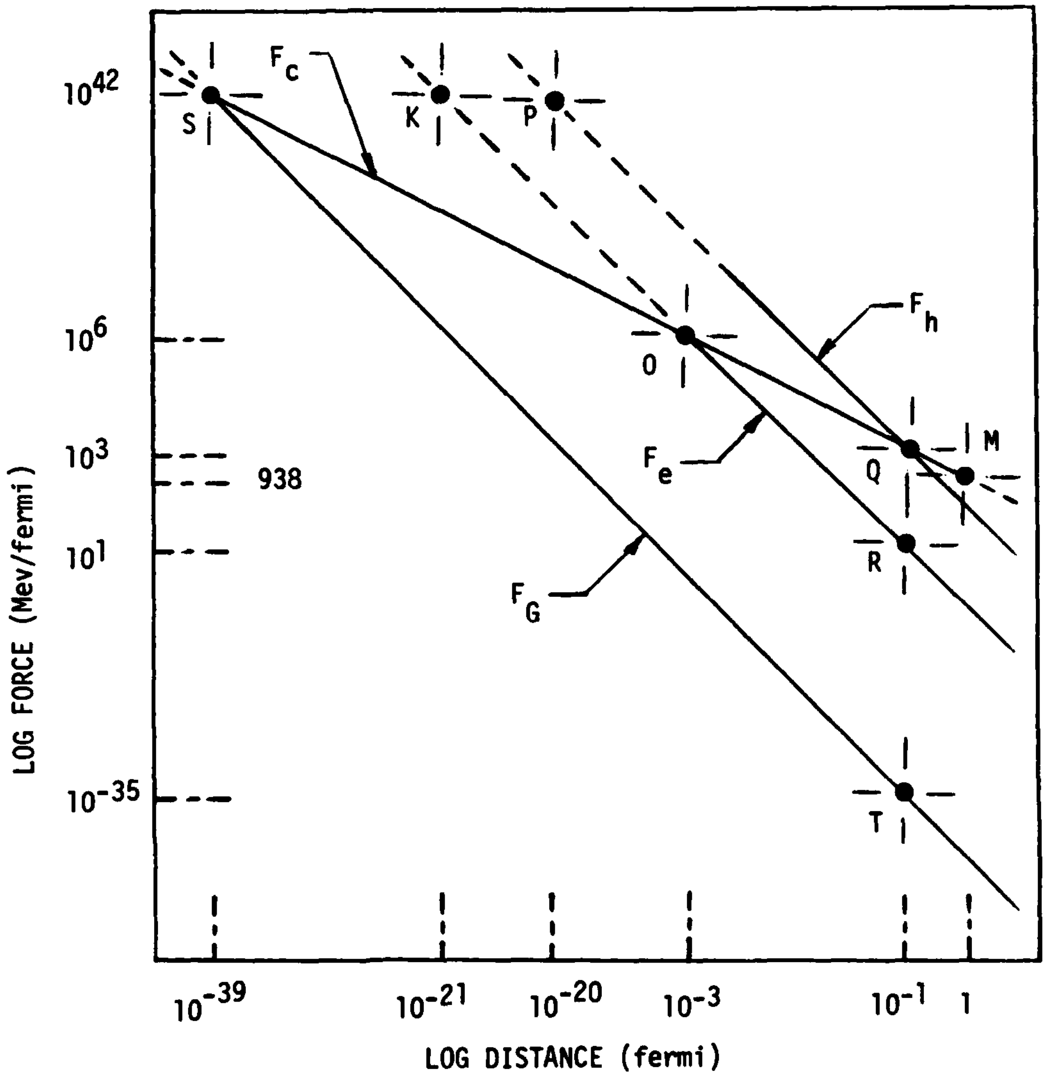

Figure 1. Plot of log force versus log distance for hypothetical proton-proton interaction based upon the redefined forces of the unified interaction theory. Solid lines are probable ranges of the forces. Not to scale but numbers approximately match points. One dyne is equivalent to 6.24×10^{-8} Mev/fm. One newton is 6.24×10^{-3} Mev/fm. Because of the units used, all forces at one fermi have the same numerical magnitude in Mev/fm as the rest mass energy in Mev (point M).

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$$r_S = \frac{mG}{c^2}$$

$$F_G = \frac{m^2G}{r_S^2}$$

$$F_G = \frac{c^4}{G} = F_S$$

The force F_S is a critical value of the Newton force at the gravitational collapse limit. The lengths at points K and P in Figure 1 can be explained in terms of equivalence of the constant force at K and P to this critical value. When the Coulomb force is equal to F_S above, $F_e = F_S$, the resulting length is a function very similar to one derived by Kursunoglu (5, p. 1539). The equivalence at point P of the Planck force with F_S, $F_h = F_S$, is a function frequently used in astrophysics, the Planck length (6, p. 12). The mass required in the Einstein force to make $F_c = F_h = F_S$ at the Planck length is the Planck mass (6, p. 1215).

A number of significant ratios of forces, one to the other, are possible from Figure 1. The ratio of F_h to F_c, which is unity at the Compton wavelength at point Q may be defined as the strong interaction coupling constant. The ratio of F_e to F_c at the Compton wavelength, F_R/F_Q, is the electromagnetic interaction coupling constant. The ratio of F_e to F_h for any constant length is the fine structure constant. The ratio of r_e to r_h at any constant force is the square root of the fine structure constant. The ratio of F_G to F_c at the Compton wavelength, F_T/F_Q, is the gravitational interaction coupling constant. The ratio of F_S to F_T, particularly for the mass of the pion, is the Eddington number. The relationship $(F_h/F_G)^2$ at any constant length is also the Eddington number. The two ratios, F_e to F_G and F_h to F_G, at the Compton wavelength, or any constant length, are principal cosmic numbers. Everyone of the above explanations is a straight-forward mathematical manipulation of the four redefined forces. No other unified theory has been able to give such a mathematical correlation of so many different relationships.

The Einstein force is both defined and predicted by the unified interaction theory. From a physical phenomena perspective the Einstein force gives the right force magnitudes over the correct

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range as measured for the strong interaction. The Einstein force fulfills theoretical and experimental expectations in being an inverse linear function of distance. The total energy relation

$$E^2 = (pc)^2 + (mc^2)^2$$

treats the rest mass energy as if it were a potential energy. In fact, all of the forces for points M, O, Q, and S can be shown to be some constant multiplied by $(mc^2)^2$. Figure 1 indicates that below the Compton wavelength, point Q, and the classical radius, point O, that the Einstein force may be exceeded by the Planck force and the Coulomb force, respectively. Both of these conditions, as well as the total energy equation, support the condition of asymptotic freedom where the electromagnetic and the weak interactions could possibly equal or exceed the strong interaction at higher system energies. The Einstein force is totally consistent with the principle of asymptotic freedom. A unique prediction of this theory is that all particles should be effected by the Einstein force. The masses of the leptons may be too small to isolate this effect from the other forces.

The Planck force has been experimentally measured (7, p. 161) on a macroscopic scale. It has been expressed in the form

$$F_h = \frac{hcA}{360d^4}$$

where d is the distance between two neutral plates of area A. This force has been attributed to quantum fluctuations. That is why the Planck force is associated with a quantum interaction. The unified interaction theory has essentially made the association, too, that the force attributed to quantum fluctuations on a macroscopic scale may be attributed to quantum fluctuations on a microscopic scale. The introduction of the Planck force accomplishes the same function already utilized in the modeling of the force coupling constants. According to Perkins (8, pp. 17-21), all of the coupling constants can be displayed as functions of $2\pi/hc$. In Figure 1, since the Einstein force is equal to the Planck force at point Q, the relative strengths of the various forces may be related to the Planck force rather than the Einstein force. In fact, this comparison may be made at larger distances. For example, the strong interaction coupling constant represented by the relationship of $2\pi g^2/hc = 10$ is the ratio of F_c to F_h at 2.1 fm, which compares to the experimental value of 2 fm reported by Meyerhof (9, p. 224). Calculation of this result is readily understood in terms of the unified interaction theory. The electromagnetic coupling constant, $\alpha = 2\pi e^2/hc$, is also easily

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developed as explained in the mathematical correlations section of this paper. Similarly, the gravitational coupling constant may be expressed as $2\pi m^2G/hc$ as required. The acceptance of the Planck force makes all of these coupling constants directly available as functions of $2\pi/hc$ without the arbitrary introduction of the Compton wavelength as a coincidental empirical length. If it is acceptable to state that the strength of the strong interaction is the relative magnitude between it and another force, such as the electromagnetic force, at the Compton wavelength for two protons or hadrons, then it should be rational to expect that the weak interaction is a similar relationship between a proton and an electron. Consequently, the relative strength of the Planck force at its Compton wavelength for an electron compared to the Planck force at its Compton wavelength for a proton is

$$\left(\frac{m_e}{m_p}\right)^2 = 2.97 \times 10^{-7}$$

This value of the weak interaction coupling constant is somewhat lower than the Fermi theory but is closer to actual measurements. If this result is used as the weak interaction coupling constant, and analogous reasoning is used as for the proton-electron coupling model in beta decay, the resulting mass of the electron's neutrino is predicted to be 2.78×10^{-4} Mev and the mass of the muon's neutrino is 5.75×10^{-2} Mev. Both of these masses would be different if the weak interaction coupling constant for neutrino generation were different from that for the proton-electron generation.

Since it has already been shown that the ratio of the Coulomb force to any Planck force at a constant distance is equal to the fine structure constant and that the consequence of r_e divided by any r_h at the same force is equal to the square root of the fine structure constant, then it follows that any Planck force magnitude is related to any other Planck force value as some function of the fine structure constant. The same is true of the relationship of any Coulomb force to another Coulomb force and of the point of equivalence of any Einstein force with the Planck force to another equivalence point. On a linear plot of force versus distance, these stair-step relationships as a function of the fine structure constant quickly diverge. These various relationships of the different forces as a function of the fine structure constant are completely analogous to the pertubation theory expansion of a series function of the fine structure constant in quantum electrodynamics.

The unified interaction theory predicts an unusual force, c^4/G, with an absolute magnitude of 7.55×10^{41} Mev/fm. The combination c^4/G is an integral part of many equations in the literature but no attention has been called to it as being a force _per se_. Because of its unique derivation from the unified interaction theory, c^4/G has been referred to by others as the Heaston force. If the experimentally observed strong interaction is 10^{39} times the gravitational force between two protons and c^4/G is 6.5×10^{77} times the gravitational force (at 1 fm), then c^4/G is 6.5×10^{38} times the strong interaction. The Heaston force is obviously a super-strong force. Such a force has been qualitatively predicted and attributed to Kaufman by Feynman (10, p. 609) and to Kogut, Wilson and Susskind by Glashow (11, p. 45). It has been suggested in both cases as a binding-force for quarks. The Heaston force is strong enough to be the mechanism for the generation of black holes as well as a significant factor in cosmology. The reason for this statement is because c^4/G appears in the Einstein field equation (6, pp. 431-434),

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}$$

as well as in almost all solutions to this equation. Conditions may be defined such that the gravitational metric is zero, the Ricci tensor is R_{oo}, and the total energy is T_{oo}. Because of conditions imposed by the Christoffel indices, a factor of one-half is introduced so that

$$R_{oo} = \frac{4\pi G}{c^4} T_{oo}$$

This is precisely the result obtained by Weyl (12, p. 242) for the case of a stationary gravitational field where he referred to the inverse of c^4/G as the greek letter kappa without indicating any awareness that kappa was an inverse force. The 4π is introduced to account for spatial density. Based upon the new awareness that c^4/G is a superstrong force, the result in the last equation may be interpreted as stating that, at the beginning of the universe, the total mass/energy of the universe was confined in the dimension R_{oo} and held together by the Heaston force.

Many physicists and astrophysicists make the assumption of physical units so that $c = h = G = 1$. Because of this assumption, c^4/G is unity and loses visibility in theoretical derivations. On the other hand, the effect of such a choice of units is to normalize all forces so that c^4/G is the maximum force possible and all other forces are relative. The unified interaction theory confirms this implication. The Heaston force is the critical value at the

gravitational collapse limit where the Newton force is equal to the Einstein force. The prediction of the Kursunoglu length at Point K in Figure 1 involves the Heaston force. Kursunoglu (5) attempted to unify the four fundamental forces based upon a time-independent spherically symmetric field solution to the field equations. He obtained a fundamental constant, $r^2 = 2Ge^2/c^4$, which he attributed to be a measure of deviation from the theory of relativity. This constant resulted from a roundabout unification of the electromagnetic and gravitational fields which Kursunoglu could not quite explain. The specific explanation is given by the unified interaction theory at point K. Accepted theories for black hole generation are based upon the Planck length which is the point where the Planck force is equal to the critical value represented by the Heaston force. The Planck mass, which is recognized as the maximum possible mass of any single particle occurs when $F_c = F_b = F_S$ in Figure 1. All of these observations support the conclusion that c^4/G may be the maximum possible force in the universe. This means that gravitational collapse reaches an asymptote rather than continuing to a singularity. The possibility of such an asymptote is predicted (6, pp. 1196-1217) as an option for theoretical definition of the universe. In his attempts to derive a unified field theory, Einstein predicted (13) that gravity, which is the weakest of all forces, should have a role to play in particle structure. The Heaston force, which is based upon the limit of gravitational collapse, fulfills the prediction by Einstein.

The unified interaction theory can be extrapolated to create a picture of the structure of a single particle. The outer "boundary" of a particle is defined as the <u>quantum surface</u>, r_Q. It occurs at the Compton wavelength created by the equivalence of the Einstein force and the Planck force. The proton has a fuzzy boundary that averages to an experimental boundary equivalent to the quantum surface. Within the particle is a "charge surface" located at the classical radius, r_0. At the heart of a particle is a gravitational core where c^4/G predominates. A three-layer structure like this has been constructed (14) for particles, particularly protons, from experimental observations. The radius of a particle is $h/2\pi mc$. The circumference is h/mc. If all of the charge is concentrated between the charge surface and the quantum surface, the rotation of a charged loop equal to the Compton wavelength in radius gives the Bohr magneton. The Einstein force is equivalent to a centripetal force at the quantum surface rotating at the constant speed of light, which correlates with one theoretical observation (15). The moment of inertia yielding such a force implies that particles have to be cylindrical discs rotating on an axis through the center of the disc. Seventeen years

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of experimental observations on the magnetic moment of the electron indicates that the best model for all of the measurements is a thin right circular cylinder (16, p. 80).

The above conditions cannot be achieved without a further consequence which is the most speculative as well as the most unique prediction of the unified interaction theory. There would be no observed changes in intrinsic spin of a particle without the following hypothetical process. Whenever a particle is accelerated (or decelerated) in translation, it changes in size in all three dimensions from a fixed size at rest to zero volume at the speed of light. This process is called trilation, as compared to translation and rotation. Lorentz made this initial assumption in his derivation (17, p. 21). It can be shown that trilation can produce the same volume change as the Lorentz-Fitzgerald contraction. Moreover, the process of trilation is essentially stated by the Schrodinger wave equation. The most common interpretation of $|\psi|^2$ is that $|\psi|^2$ is the probability that a particle can be found in a box or phase space of arbitrary volume. Suppose that this volume were the rest mass volume. Consequently, when a particle is accelerated, the probability $|\psi|^2$ of the particle occupying its rest mass volume at rest is unity and the corresponding probability at the speed of light is zero. Nothing is changed but the interpretation. Volume is also a hidden variable in relativity theory. Forces are expressed as forces per unit volume (6, p. 159; 12, pp. 64 and 201; 17, p. 13) as well as for only a small volume of space. The trilation process is normalized into the theoretical results. Thus, the proposed model of particle behavior is as follows. A particle absorbs energy. It is accelerated as it changes size. In order to compensate for conservation of angular momentum and to maintain its constant quantum surface rotation at the speed of light, part of the energy is dumped overboard. Maxwell's equations are obeyed. Intrinsic spin is coupled to translation. Quantum numbers may be logically related. Rotation of the quantum surface in revolutions per second is the same as the frequency in $E = h\nu$. Deltas in spins, rather than absolute values, are explained. The particle has a built-in capability to recall its total energy state in any relativistic situation. Collision cross sections decrease with higher energy. Wave-particle duality has an integral physical justification. Spin speeds have a boundary. Quantized behavior has a physical interpretation. Based upon this model, a resonance particle is one that cannot hold together for more than one revolution. Its quantum surface does not develop.

Finally, an overall assessment of Figure 1 and the unified interaction theory indicates an extraordinary paradox. Points M, O, Q, R, and T in Figure 1 are concerned with forces and dimensions such as the coupling constants, fine structure constant, Compton wavelength and classical radius which are all relationships familiar to high energy physics. These phenomena are usually associated with dimensions of 0.001 to 1 fermi. On the other hand, points K, P, and S which contribute to defining the gravitational collapse limit, Planck length, Planck mass and c^4/G are part of the language of astrophysics and cosmology. The dimensions associated with these points range from 10^{-39} to 10^{-20} fm. The paradox exists in that the world of galaxies and megaparsecs is dependent upon relationships derived from conditions dependent upon dimensions orders of magnitude less than the conditions associated with the microscopic world of particle physics which takes place at the relatively long range of one fermi. It is extraordinary that the equation for the gravitational collapse limit at point S and 10^{-39} fm for a proton is also extrapolated in astrophysics into the empirical relationship, $MG/Rc^2 \cong 1$, where M is the mass of the universe and R is the radius of the universe (18, p. 1162). The reason for this paradox is that the large magnitudes of c^4/G and the inverses of the extremely small dimensions give the large numbers that are needed in cosmology. That is the very reason why every large cosmic number, except the Hubble constant (which is obtained from telescopic observations) can be constructed from various ratios of forces and distances in Figure 1. The major achievement of the unified interaction theory may very well be this explanation for the first time of the close association between the relationships of physics and astrophysics.

CONCLUSIONS

After the initial hypothesis that $E = mc^2$ and $E = h\nu$ are functions of potentials that have corresponding forces in the structure of matter, all of the manipulations of the unified interaction theory are mathematically and dimensionally precise as well as internally consistent. No other theory has been able to give a coherent integrated explanation of so many different relationships of physics and astrophysics. A long desired goal of relating general relativity to quantum mechanics may have been achieved. Although the language is the same, the interpretations using the unified interaction theory are often different. The phenomena are accepted at face value but the cause and effect explanations are not the same. Experiments could possibly be devised to test the predictions of the Einstein and the Planck forces and their application to all particles, the masses of the neutrinos, the existence of the quantum surface, the

coupling of the quantum numbers, the internal structure of particles, the trilation process, and the role of the fine structure constant. Effects of the Heaston force may be implied only indirectly but its main value should be in theoretical developments in cosmology. The ultimate value of the redefined forces will probably be their use as a key step in explaining the different particle masses. A whole new world below one fermi has been opened up. The mathematical unity of the unified interaction theory is so overwhelming that serious attempts should be made to verify or disprove the predictions resulting from redefining the four fundamental forces.

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